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(71) Applicant(s)

Alps Electric Co Ltd

(Incorporated in Japan)

1-7 Yukigaya, Otsuka-cho, Ota-ku, Tokyo 145, Japan

(72) Inventor(s)

Jun Sugawara

(74) Agent and/or Address for Service

Michael A Enskat & Co

9 Rickmansworth Road, Watford, Herts, WD1 7HE,  
United Kingdom

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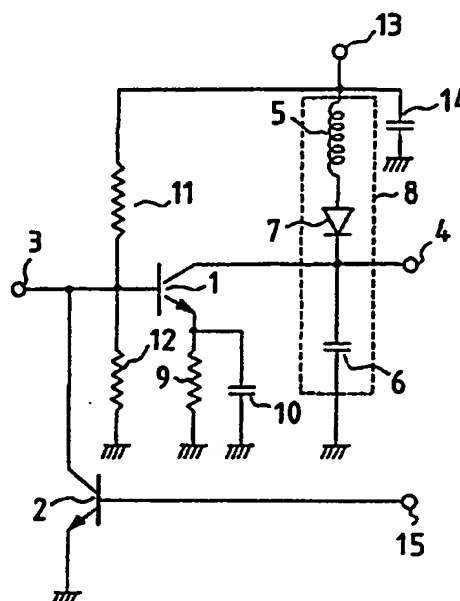
INT CL<sup>5</sup> H03F 3/72

Online databases: WPI

## (54) High frequency amplifier

(57) A high frequency amplifier has an amplifying transistor 1 whose operation mode can be selectively switched between active and inactive modes. A switch such as switching transistor 2 selectively grounds the base of the amplifying transistor 1, a resonant circuit 8 is connected to the collector of the amplifying transistor 1, and a diode 7 is inserted in a circuit path of the resonant circuit 8 so that the collector current of the amplifying transistor 1 flows through the diode 7. When the amplifying transistor 1 is in the off state, the diode 7 is also in the off state and thus the diode acts as a capacitor having a small capacitance, whereby the resonant frequency of the resonant circuit 8 becomes significantly higher than the resonant frequency that is obtained when the amplifying transistor 1 is in the on state. In the inactive operation mode, therefore, the signal frequency component is attenuated to a sufficiently low level by the resonant circuit 8 having a resonant frequency higher than the signal frequency. The amplifier may be used as an RF amplifier (23, Fig 1) in a transmitter (20) of a transmitter/receiver communication system. Switching between the transmitter (20) and the receiver (21) is obtained by a transmit/receive signal (38). The communication system may be a time division multiplex system.

FIG. 2



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FIG. 1

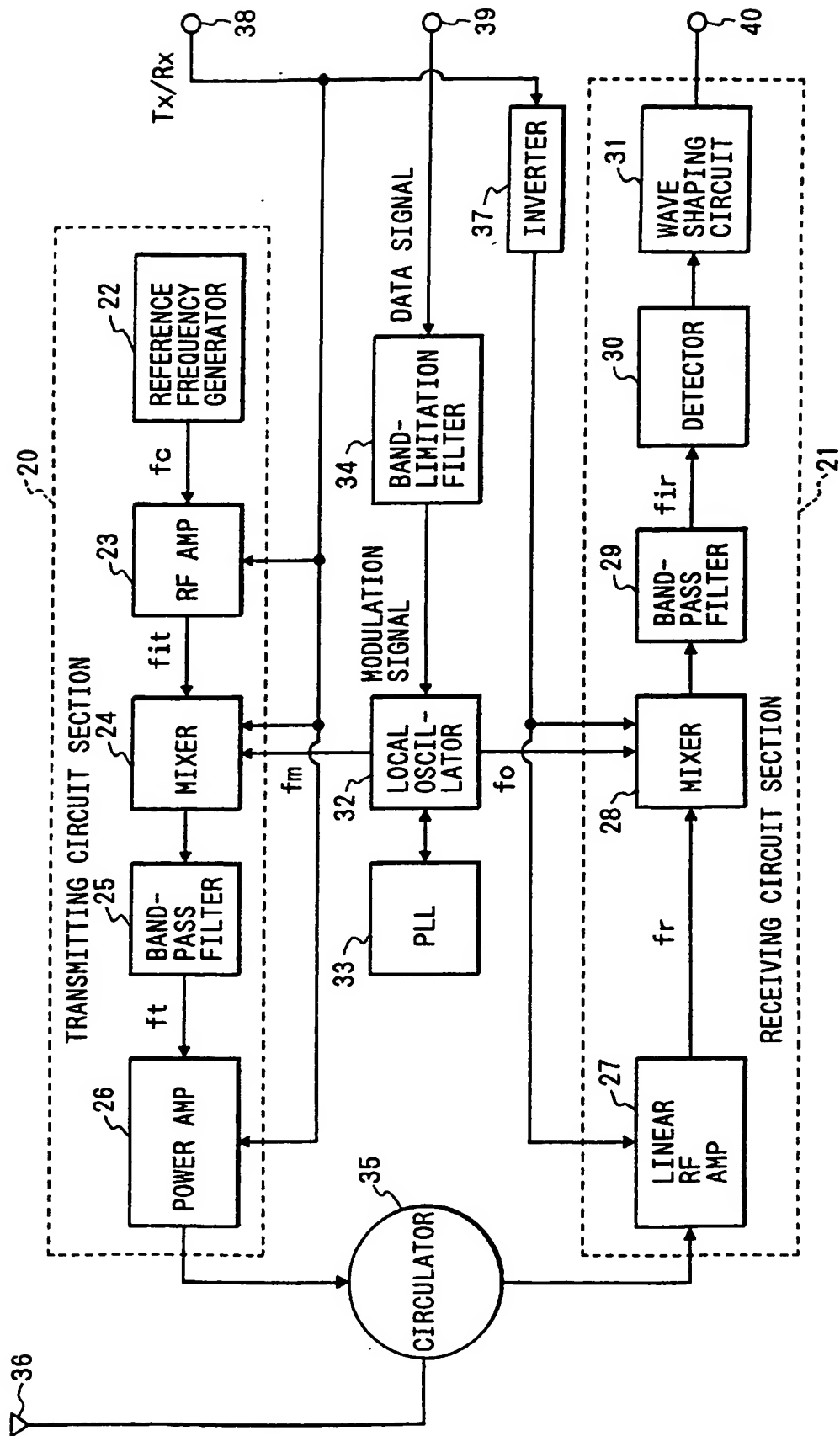


FIG. 2

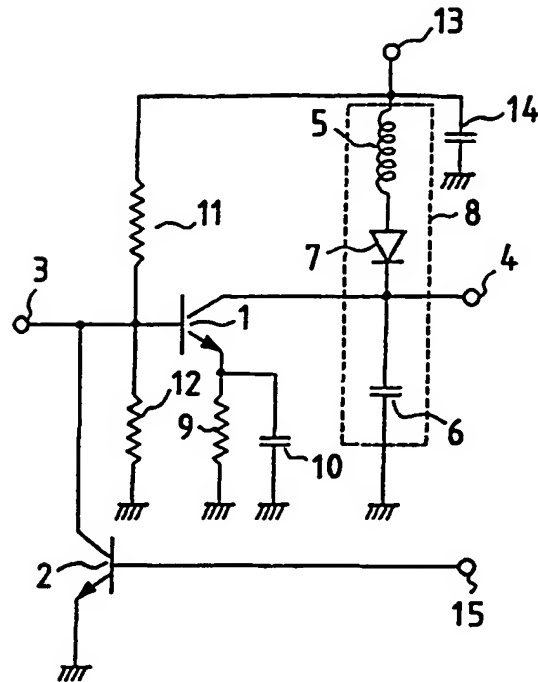
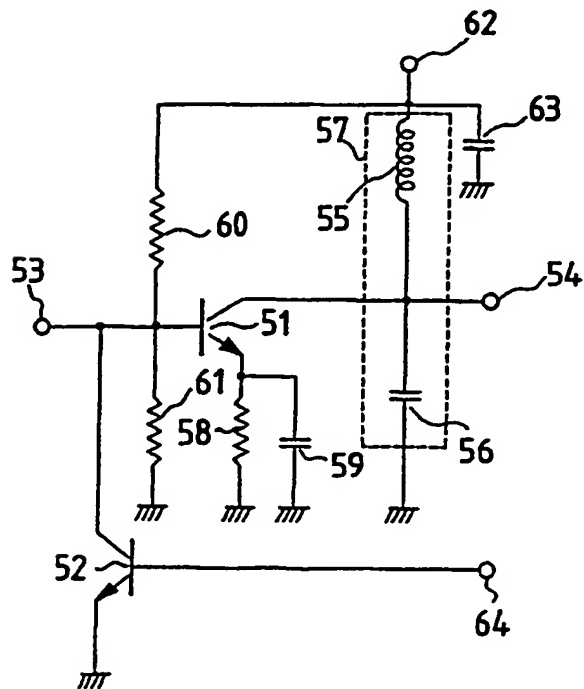


FIG. 3



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HIGH FREQUENCY AMPLIFIER

This invention relates to a high frequency transistor amplifier capable of selectively switching its operation mode between active and inactive states. More specifically, the present invention relates to a high frequency transistor amplifier for use in a time division duplex radio communication system, the amplifier having means for selectively amplifying-and-multiplying/amplifying or cutting off a reference frequency signal used as a base of a transmission carrier signal, wherein the amount of the reference frequency signal leaking to a receiving circuit section in the cutoff operation mode is attenuated to a sufficiently low level.

In FDMA (frequency division multiple access)/TDD (time division duplex) radio communication systems, the circuit described below is often used.

Figure 1 is a block diagram illustrating an example of a known configuration of transmitting and receiving circuit sections in a FDMA or TDMA/TDD radio communication system (TDMA: Time Division Multiple Access).

Figure 1 shows a transmitting circuit section 20, a receiving circuit section 21, a reference frequency generator 22, a high frequency amplifier 23, a first frequency mixer 24, a first band-pass filter 25, a power amplifier 26, a linear high frequency amplifier 27, a second frequency mixer 28, a second band-pass filter 29, a detector 30, a wave shaping circuit 31, a local oscillator 32, a phase-locked loop circuit 33, a band limitation filter 34, a circulator 35, an antenna 36, an inverter 37, a transmission/reception switching terminal 38, a data signal input terminal 39, and a data output terminal 40.

The transmitting circuit section 20 includes the reference frequency generator 22, the high frequency

amplifier 23, the first frequency mixer 24, the first  
band-pass filter 25, and the power amplifier 26. The  
receiving circuit section 21 includes the linear high  
frequency amplifier 27, the second frequency mixer 28, the  
5 second band-pass filter 29, the detector 30, and the wave  
shaping circuit 31. The reference frequency generator 22  
in the transmitting circuit section 20 generates a  
stabilized reference frequency signal  $f_c$ , wherein a  
transmission intermediate frequency signal  $f_{it}$  is  
10 generated based on this reference frequency signal  $f_c$ . A  
crystal oscillator, for example, is used as the reference  
frequency generator 22. The high frequency amplifier 23  
amplifies and frequency-multiplies or simply amplifies the  
reference frequency signal  $f_c$  to generate the transmission  
15 intermediate frequency signal  $f_{it}$ . The first frequency  
mixer 24 mixes the transmission intermediate frequency  
signal  $f_{it}$  and a modulated signal  $f_m$  provided by the local  
oscillator 32. In this operation, the high frequency  
amplifier 23 acts as a frequency modulator. The first  
20 band-pass filter 25 selectively extracts a modulated  
transmission signal  $f_{ft}$  from a mixed signal produced by the  
first frequency mixer 24. The power amplifier 26  
amplifies the power of the modulated transmission signal  
 $f_{ft}$  to the required transmission level. In the receiving  
25 circuit section 21, the linear high frequency amplifier 27  
performs linear amplification on a received high frequency  
signal  $f_r$ , and the second frequency mixer 28 mixes the  
linear-amplified high frequency signal  $f_r$  and the local  
oscillation signal  $f_o$ . The second band-pass filter 29  
30 selectively extracts a reception intermediate frequency  
signal  $f_{ir}$  from a mixed signal produced by the second  
frequency mixer 28. The detector 30 detects the  
reception intermediate frequency signal  $f_{ir}$  to extract a  
data signal, and the extracted data signal is shaped by  
35 the wave shaping circuit 31.

The band limitation filter 34 performs band limitation processing on the data signal that is input via the data signal input terminal 39 in the transmitting operation, and then supplies the band-limited data signal as a modulation signal to the local oscillator 32. The circulator 35 supplies the modulated transmission signal  $f_t$  from the transmitting circuit section 20 to the antenna 36, and also supplies the high frequency signal  $f_r$  received with the antenna 36 to the receiving circuit section 21. A transmission/reception switching control signal is applied to the transmission/reception switching terminal 38. This transmission/reception switching control signal is directly supplied to the high frequency amplifier 23 and the first frequency mixer 24, and also supplied via the inverter 37 to the linear high frequency amplifier 27 and the second frequency mixer 28.

The operation of the above-described radio communication system is as follows.

In transmission operation, a transmission switching signal  $T_x$  is applied to the transmission/reception switching terminal 38, whereby circuit blocks in the transmitting circuit section 20 including the high frequency amplifier 23, the first frequency mixer 24, and the power amplifier 26 are all made active, and circuit blocks in the receiving circuit section 21 including the linear high frequency amplifier 27 and the second frequency mixer 28 are both made inactive. In this operation mode, the reference frequency signal  $f_c$  generated by the reference frequency generator 22 is amplified and multiplied, or otherwise simply amplified, by the high frequency amplifier 23. Then, the high frequency amplifier 23 outputs the transmission intermediate frequency signal  $f_{it}$  to the first frequency mixer 24. The data signal that is input via the data signal input terminal 39 is subjected to band

limitation processing by the band limitation filter 34, and then supplied as the modulation signal to the local oscillator 32, whereby the local oscillation signal fo is modulated by the modulation signal thereby producing a modulated signal fm. The first frequency mixer 24 mixes the transmission intermediate frequency signal fit and the modulated signal fm, and provides a mixed output to the first band-pass filter 25 which selectively extracts the modulated transmission signal ft from the mixed output, and supplies it to the power amplifier 26. The power amplifier 26 amplifies the power of the modulated transmission signal ft up to the transmission level, and then supplies it to the antenna 36 via the circulator 35. The modulated transmission signal ft is radiated from the antenna 36.

During the transmission operation, the circuit blocks in the receiving circuit section 21 including the linear high frequency amplifier 27 and the second frequency mixer 28 are in the inactive state, as described above. Therefore, even if the modulated transmission signal ft or the transmission intermediate frequency signal fit leaks to the receiving circuit section 21, these leakage signals cannot interfere to the receiving circuit section 21.

In a receiving operation, on the other hand, a reception switching signal Rx is applied to the transmission/reception switching terminal 38, whereby the circuit blocks in the transmitting circuit section 20 including the high frequency amplifier 23, the first frequency mixer 24, and the power amplifier 26 are all made inactive, and the circuit blocks in the receiving circuit section 21, including the linear high frequency amplifier 27 and the second frequency mixer 28 are both made active. In this receiving operation, the high frequency signal fr received with antenna 36 is applied to

the linear high frequency amplifier 27 via the circulator 35. The linear high frequency amplifier 27 amplifies linearly the high frequency signal  $f_r$  and then supplies it to the second frequency mixer 28. The second frequency  
5 mixer 28 mixes the high frequency signal  $f_r$  and the local oscillation signal  $f_o$  generated by the local oscillator 32, and then supplies the mixed output to the second band-pass filter 29. The second band-pass filter 29 selectively extracts the reception intermediate frequency  
10 signal  $f_{ir}$ , and supplies it to the detector 30. The detector 30 demodulates the reception intermediate frequency signal  $f_{ir}$  to reproduce the data, and then supplies it to the wave shaping circuit 31. The wave shaping circuit 31 shapes the wave form of the data, and  
15 supplies the data to a data processing section (not shown) via the data output terminal 40.

The reference frequency generator 22 does not play any role in the receiving operation. However, it is still in operation during the receiving operation, because  
20 if it is made inactive once, then instability in the output frequency will occur for a while after restarting of oscillation.

Figure 3 is a circuit diagram showing an example of a known circuit configuration used for the high  
25 frequency amplifier 23 in the transmitting circuit section 20.

The figure shows an amplifying transistor 51, a switching transistor 52, an input signal terminal 53, an output signal terminal 54, an inductor 55, a capacitor 56,  
30 a resonant circuit 57, an emitter resistor 58, a bypass capacitor 59, base bias resistors 60, 61, a power supply terminal 62, a bypass capacitor 63, and a transmission/reception switching terminal 64.

In this circuit, the base of the amplifying  
35 transistor 51 is connected to the input signal terminal 53

and the collector of the switching transistor 52. The emitter of the amplifying transistor 51 is grounded via the parallel connection of the emitter resistor 58 and the bypass capacitor 59. The collector of the amplifying  
5 transistor 51 is connected to the output signal terminal 54 and the resonant circuit 57 via the resonant circuit 57 comprising the inductor 55 and the capacitor 56. The base of the switching transistor 52 is connected to the transmission/reception switching terminal 64, and the  
10 emitter of the switching transistor 52 is directly grounded. The other end of the inductor 55 is connected to the power supply terminal 62, and the other end of the capacitor 56 is grounded.

In transmission operation, a transmission  
15 switching signal having a voltage approximately equal to the ground potential is applied to the transmission/reception switching terminal 64. This transmission switching signal makes the switching transistor 52 cut off. As a result, the base bias  
20 voltage, defined by the base bias resistors 60 and 61, is applied to the base of the amplifying transistor 51, and thus the amplifying transistor 51 is made to be in a normal operation state. Thus, the reference frequency signal supplied via the input signal terminal 53 is  
25 amplified by the amplifying transistor 51 whereby the amplified signal is generated at the collector of the amplifying transistor 51. The collector of the amplifying transistor 51 is connected to the resonant circuit 57 tuned to the second harmonic of the reference  
30 frequency signal, whereby only the second harmonic signal is selectively extracted from the amplified signal. The extracted signal is supplied as the transmission intermediate frequency signal to the first frequency mixer (not shown) through the output signal terminal 54.

35 In receiving operation, a reception switching

signal having a positive voltage is applied to the transmission/reception switching terminal 64. As a result, the switching transistor 52 is turned on, whereby the base of the amplifying transistor 51 is grounded via the switching transistor 52. Therefore, the amplifying transistor 51 is made to be in an inactive state (cutoff state) in which the amplifying transistor 51 cannot perform the amplification operation. In this operation mode, even if the reference frequency signal is applied to the base of the amplifying transistor 51, this reference frequency signal cannot appear at the collector of the amplifying transistor 51. Moreover, the transmission intermediate frequency signal is not applied to the succeeding first frequency mixer (not shown) via the output signal terminal 54.

Even in the inactive state (cutoff state), the transistor still has base-collector junction capacitance as well as base-emitter junction capacitance. Also, in the active state (on state), the transistor has residual impedance between its emitter and collector. Therefore, when the switching transistor 52 is in the on state and at the same time the amplifying transistor 51 is in the inactive state (cutoff state), the reference frequency signal  $f_c$  having a rather high frequency is neither perfectly shunted with the switching transistor 52 because of the presence of the residual impedance of the switching transistor 52, nor perfectly cut off by the amplifying transistor 51 because of the presence of the base-collector junction capacitance of the amplifying transistor 51. Thus, a part of the reference frequency signal is transmitted to the collector side of the amplifying transistor 51.

The second harmonic of the reference frequency signal is selectively extracted by resonant circuit 57 and is output to the outside of the high frequency amplifier

via the output signal terminal 54. Thus, interference occurs to the receiving circuit section 21 that is in receiving operation.

5 The present invention arose in an attempt to solve the above problem. More specifically, it is an object of the present invention to provide a high frequency amplifier having an amplifying transistor that is capable of selectively switching the operation mode between an active state and an inactive state, wherein the  
10 output signal component leaking when the amplifying transistor is in the inactive state is reduced to a sufficiently low level.

According to the present invention there is provided a high frequency amplifier comprising: a  
15 transistor connected in common-emitter configuration for high frequency amplification; a switching means (e.g. a switching transistor) for selectively grounding the base of the transistor for amplification; a resonant circuit connected to the collector of the transistor for  
20 amplification; wherein the high frequency amplifier is characterized in that the high frequency amplifier includes means which comprise a diode disposed within the resonant circuit such that a collector current is supplied via the diode to the transistor for the amplification.

25 The high frequency amplifier with the above means according to the present invention operates as follows. In receiving operation, a switching signal is applied to the base of the switching transistor so that the switching transistor is turned on, whereby the base of  
30 the amplifying transistor is grounded thereby making the amplifying transistor cut off. In this state, the diode connected to the collector of the amplifying transistor is cut off, and thus equivalently acts as a capacitor having small capacitance. As a result, the resonant frequency  
35 of the resonant circuit including the diode becomes

significantly higher than that in the opposite operation state.

Embodiments of the invention will now be described by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a block diagram illustrating an example of a circuit configuration of transmission/reception circuit sections for use in FDA or TDMA/TDD radio communication system, to which a high frequency amplifier according to the present invention is to be applied;

Figure 2 is a circuit diagram illustrating a circuit configuration of an embodiment of a high frequency amplifier according to the present invention; and

Figure 3 is a circuit diagram illustrating an example of a conventional high frequency amplifier.

Figure 2 shows a circuit configuration of one embodiment of a high frequency amplifier according to the present invention, which is applicable to the high frequency amplifier 23 shown in Figure 1.

In Figure 2, there are shown an amplifying transistor 1, a switching transistor (switching means) 2, an input signal terminal 3, an output signal terminal 4, an inductor 5, a capacitor 6, a diode 7, a resonant circuit 8, an emitter resistor 9, a bypass capacitor 10, base bias resistors 11, 12, a power supply terminal 13, a bypass capacitor 14, and a transmission/reception switching terminal 15.

In this circuit, the resonant circuit 8 is formed with the inductor 5, the capacitor 6, and the diode 7, wherein the inductor 5 and the diode 7 are connected in series between the output signal terminal 4 and the power supply terminal 13, and the capacitor 6 is connected between the output signal terminal 4 and ground. The base of the amplifying transistor 1 is connected to the

input signal terminal 3 and the collector of the switching transistor 2. The emitter of the amplifying transistor 1 is grounded via a parallel connection of the emitter resistor 9 and the bypass capacitor 10. The collector of the amplifying transistor 1 is connected to the output signal terminal 4 and the resonant circuit 8. The base of the switching transistor 2 is connected to the transmission/reception switching terminal 15, and the emitter of the switching transistor 2 is directly grounded. The input signal terminal 3 receives the reference frequency signal  $f_c$  from the reference frequency generator 22 (refer to Figure 1). When the diode 7 is on, the resonant circuit 8 exhibits a resonant frequency equal to the second harmonic frequency  $2f_c$  of the reference frequency signal  $f_c$  so that the second harmonic signal  $2f_c$  may be output as the transmission intermediate frequency signal  $f_{it}$  via the output signal terminal 4.

The high frequency amplifier according to the present embodiment operates in the following manner.

In transmitting operation, a transmission switching signal Tx having a voltage approximately equal to the ground potential is applied to the transmission/reception switching terminal 15. This transmission switching signal Tx makes the switching transistor 2 cut off. As a result, the base bias voltage, defined by the base bias resistors 11 and 12, is applied to the base of the amplifying transistor 1, and thus the amplifying transistor 51 is made to be in a normal operation state. Thus, the reference frequency signal supplied via the input signal terminal 3 is amplified by the amplifying transistor 1 configured in the common-emitter fashion, whereby the amplified signal is generated at the collector of the amplifying transistor 1. In this operation mode, the collector current of the amplifying transistor 1 flows through the diode 7, and

thus the diode 7 is in the on state, whereby the resonant frequency of the resonant circuit 8 becomes equal to the second harmonic frequency  $2f_c$  of the reference frequency signal  $f_c$ . As a result, only the second harmonic  $2f_c$  of the amplified reference frequency signal  $f_c$  is selectively  
5 extracted by the resonant circuit 8, and the extracted signal is output as the transmission intermediate frequency signal fit to the first frequency mixer 24 (refer to Figure 1) via the output signal terminal 4.

10 In receiving operation, a reception switching signal Rx having a positive value is applied to the transmission/reception switching terminal 15. As a result, the switching transistor 2 is turned on, whereby the base of the amplifying transistor 1 becomes grounded  
15 via the switching transistor 2 in the on state. Thus, the amplifying transistor 1 is made to be in the inactive state (cut off state), in which the amplification operation is not performed. In this operation state, the reference frequency signal  $f_c$  is not perfectly shunted  
20 with the switching transistor 2 because of the presence of the residual impedance of the switching transistor 2, and not perfectly cut off by the amplifying transistor 1 because of the presence of the base-collector junction capacitance of the amplifying transistor 1. Thus, a part  
25 of the reference frequency signal is transmitted to the collector side of the amplifying transistor 1.

However, when the amplifying transistor 1 is in the inactive state (cut off state), there is no collector current flowing through the diode 7 of the resonant  
30 circuit 8, and thus the diode is in the cut off state and the diode acts as a capacitor having a small capacitance. This means that the capacitor having the small capacitance is connected in series to the inductor 5 of the resonant circuit 8, and thus the resonant frequency becomes much  
35 higher than the predetermined frequency equal to the

second harmonic frequency  $2f_c$ . In this state, the second harmonic signal  $2f_c$  of the reference frequency signal  $f_c$  and any signals having a frequency near the second harmonic frequency  $2f_c$  appearing at the collector of the amplifying transistor 1, that is, the reception intermediate frequency signal  $f_{ir}$  and any signals having a frequency near it are all attenuated and removed by the resonant circuit 8.

In comparison between the high frequency amplifier of the present embodiment and the conventional one regarding the second harmonic signal  $2f_c$  actually measured when the switching transistor 2 or 52 is on, that of the present embodiment is about -78 dbm, while that of the conventional one is about -60 dbm. Furthermore, the actually measured suppression ratio of the second harmonic signal  $2f_c$  between the on and off states of the switching transistor 2 or 52 is about 60 db for the present embodiment, and about 39 db for the conventional one. These results show that the present embodiment can provide significantly improved characteristics.

In this embodiment, the resonant frequency of the resonant circuit 8 in the active operation mode is set to twice the reference frequency signal  $f_c$ . However, the present invention is not limited to this. The resonant frequency of the resonant circuit 8 may also be equal to the reference frequency signal  $f_c$ , or may be set to an integral number, greater than two, times the reference frequency signal  $f_c$ .

In the present invention, as described above, during the inactive operation mode of the amplifying transistor 1 in which a switching signal is applied to the base of the switching transistor 2 so that the switching transistor 2 is turned on thereby making the base of the amplifying transistor 1 grounded so as to make the collector current of the amplifying transistor 1 zero, the

diode 7 in the resonant circuit 8, (which diode is connected to the collector of the amplifying transistor 1), is in the cutoff state and equivalently acts as a capacitor having small capacitance whereby the resonant frequency of the resonant circuit 8 including the diode 7 becomes significantly higher than the resonant frequency in the active operation mode. As a result, the signal component leaking to the collector of the amplifying transistor 1 through the junction capacitance or the like of the amplifying transistor 1 in the inactive state, wherein the leakage signal component has a frequency equal to the resonant frequency in the active mode, is attenuated to a sufficiently low level by the resonant circuit 8 including the diode 7.

Therefore, the high frequency amplifier according to the present invention can be advantageously applied to the high frequency amplifier 23 for use in the transmitting circuit section 20 of a radio communication system so that, during the receiving operation mode in which the high frequency amplifier 23 is in the inactive state, the reference frequency signal  $f_c$  generated by the reference frequency generator 22 may be attenuated to a sufficiently low level by the high frequency amplifier 23 thereby preventing the transmission intermediate frequency signal  $f_{it}$ , that is produced from the reference frequency signal  $f_c$ , from the ingress into the receiving circuit section 21 and thus from interfering to the receiving operation of the receiving circuit section 21.

CLAIMS

1. A high frequency amplifier comprising a high frequency amplification transistor, a switching means for selectively grounding the base of said transistor, and a resonant circuit connected to the collector of said transistor, wherein a diode is connected to said resonant circuit such that the collector current of said transistor is supplied through said diode.
2. A high frequency amplifier according to Claim 1, wherein said high frequency amplifier is used in a transmitting circuit section of a time division duplex radio communication system, said high frequency amplifier amplifying or multiplying a reference frequency signal, the reference frequency signal being applied to the base of said transistor, the resonant frequency of said resonant circuit being set to a frequency equal to said reference frequency signal or a harmonic of said reference frequency signal when said diode is in the on state.
3. A high frequency amplifier according to Claim 1 or Claim 2, wherein said switching means comprises a switching transistor, the collector of said switching transistor being connected to the base of said high frequency amplification transistor, the emitter of said switching transistor being grounded, wherein said switching transistor is turned on or turned off responding to the receiving or transmitting operation of said radio communication system.
4. A high frequency amplifier according to any one of the preceding claims, wherein said diode is connected in series to a coil forming said resonant circuit.
5. A high frequency amplifier according to any one of the preceding claims, wherein said resonant circuit is a parallel resonant circuit.
6. A high frequency amplifier according to Claim 4 or Claim 5, wherein said coil and said diode are connected

between the collector of said transistor and a power supply terminal, and a capacitor forming said resonant circuit is connected between the collector of said transistor and the ground.

5     7.           A high frequency amplifier substantially as hereinbefore described with reference to and as illustrated by, Figure 2 of the accompanying drawings.

8.           A time division duplex radio communication system, including a high frequency amplifier as claimed in  
10   any preceding claim

**Patents Act 1977**  
**Examiner's report to the Comptroller under Section 17**  
**(The Search report)**

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**Relevant Technical Fields**

(i) UK Cl (Ed.M) H3W (WGA)

(ii) Int Cl (Ed.5) H03F 3/72

Search Examiner  
B J EDE

Date of completion of Search  
15 JUNE 1994

**Databases (see below)**

(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii) ONLINE DATABASES: WPI

Documents considered relevant following a search in respect of Claims :-  
1-8

**Categories of documents**

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| <b>X:</b> Document indicating lack of novelty or of inventive step.   | <b>P:</b> Document published on or after the declared priority date but before the filing date of the present application.        |
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Category	Identity of document and relevant passages	Relevant to claim(s)
X	GB 2157907 A (ALPS ELECTRIC) see 11, 37, 40 Figure 8	1
X	GB 1145872 (TELEFUNKEN) see S, Tr1 or Tr2, D1 or D2 the figure and description thereof	1, 4-6
X	EP 0500434 A1 (MATRA) see 7.1 or 7.2, 3, 5, 13.1, 13.2, 14, 14.2, the figure	1, 4-6

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